Sonoma Technology, Inc.

DETECTING SOURCE ACTIVITIES AND RECONCILING AMBIENT MEASUREMENT VARIATIONS WITH FIELD OBSERVATIONS

California Regional PM_{10} and $PM_{2.5}$ Air Quality Study (CRPAQS)
Data Analysis Task 4.3

TECHNICAL MEMORANDUM
STI-902328-2579-TM

By:
Kiren E. Bahm
Dana Coe Sullivan
Lyle R. Chinkin
Kyle E. Broaders
Sonoma Technology, Inc.
Petaluma, CA

Prepared for:
California Air Resources Board
Sacramento, CA

July 2004

1360 Redwood Way, Suite C • Petaluma, CA 94954-1169

707/665-9900 • www.sonomatech.com

Sonoma Technology, Inc.

1360 Redwood Way, Suite C
Petaluma, CA 94954-1104
707 / 665-9900
Fax 707 / 665-9800
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1001 "I" Street
Sacramento, CA 95814

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ACKNOWLEDGMENTS

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1. INTRODUCTION

It is often difficult to quantify the effects of local emissions sources on ambient air quality measurements. In an effort to determine the potential effect of local short-term emissions-related events, we have constructed a continuous, 4-month photographic record of the immediate area surrounding the Angiola air quality monitoring site. This site is one of the key monitoring sites in the California Regional PM_{10}/$PM_{2.5}$ Air Quality Study (CRPAQS) of California's San Joaquin Valley, and is shown in **Figure 1-1**.

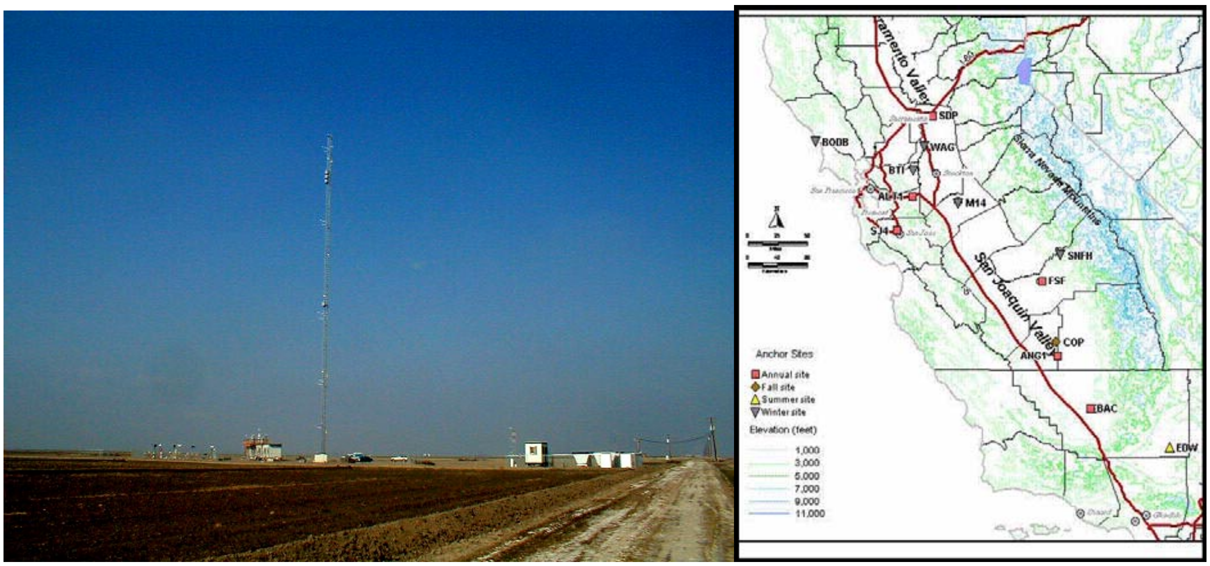


Figure 1-1. The Angiola air quality monitoring site.

2. APPROACH

The study was comprised of three main parts:

1) Identifying local emissions events using camera images taken of the area surrounding the Angiola site,
2) Classifying identified emissions events as upwind or downwind of the air quality monitors, and
3) Comparing air quality measurements that were taken during an upwind local event and those that were taken when no local emissions events were observed.

Digital cameras at Angiola captured a 360-degree view of the surrounding area every two to three minutes during daylight hours from September 2000 through January 2001. The site had four cameras each pointing directly north, east, south, or west as shown in **Figures 2-1 and 2-2**. The photographic images were used to determine the specific time periods during which local emission sources were observable, the type of source, and its location with respect to the air quality monitors. General types of sources included autos, diesel trucks, and field work. Each image was classified as having one or more emissions sources present, having no emissions sources present, or as a missing or bad image. The categories established were

1. Emissions present – Car
2. Emissions present – Gas truck
3. Emissions present – Diesel truck
4. Emissions present – Field work
5. No emissions present
6. Bad image or image not available

Cars and gas trucks were classified as emissions sources when a change of the vehicle's location was observed between consecutive images. When the vehicle was stationary the image was not classified as containing an emissions source. Diesel trucks were assumed to be running during the entire time they were present in the images (usually 5-20 minutes), unless they remained stationary at the site for more than 30 consecutive minutes. Over 140,000 images were reviewed and classified for this part of the study. Examples of the images are shown below in **Figures 2-1 through 2-6**.

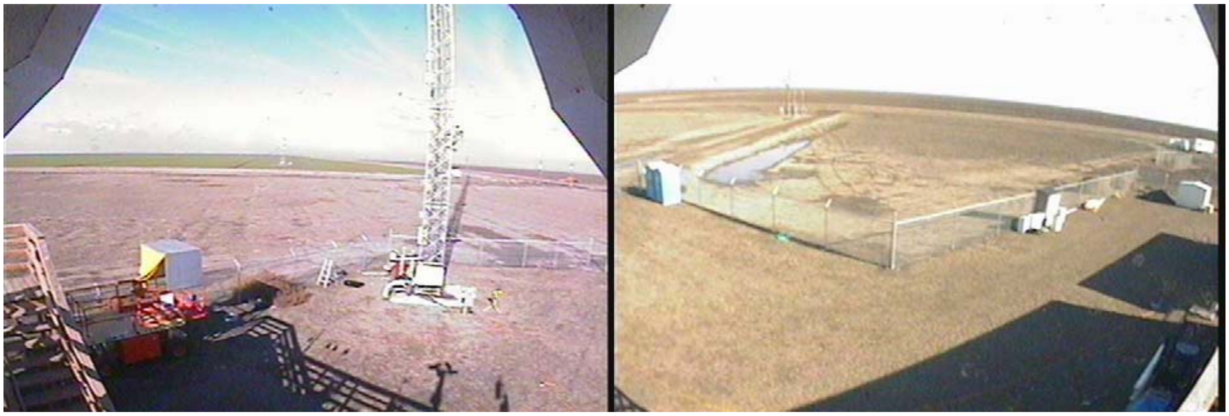


Figure 2-1. Looking north and east from Angiola (no emissions present).

Figure 2-2. Looking south and west from Angiola (no emissions present).

Figure 2-3. Examples of bad images.

Figure 2-4. Cars and diesel truck present (left), car and non-diesel truck present (right).

Figure 2-5. Scissor lift present (classified as non-diesel truck).

Figure 2-6. Field work present.

The location of each source relative to the monitors was determined during the classification of each image. A map of the Angiola site is given in **Figure 2-7**, and shows the locations of the emissions sources relative to the site. The image-derived emissions data were used to classify the time between September 27, 2000 and January 31, 2001 as to which sources were observed in the area during daylight hours. Five-minute and 60-minute time intervals were used in the time classification. Time intervals defined as having "no emissions present" had no observed influences within any of the images taken during the time interval. Only time periods when one or more emissions sources were observed in greater than 10% of the images taken during the interval were defined as having local influences present.

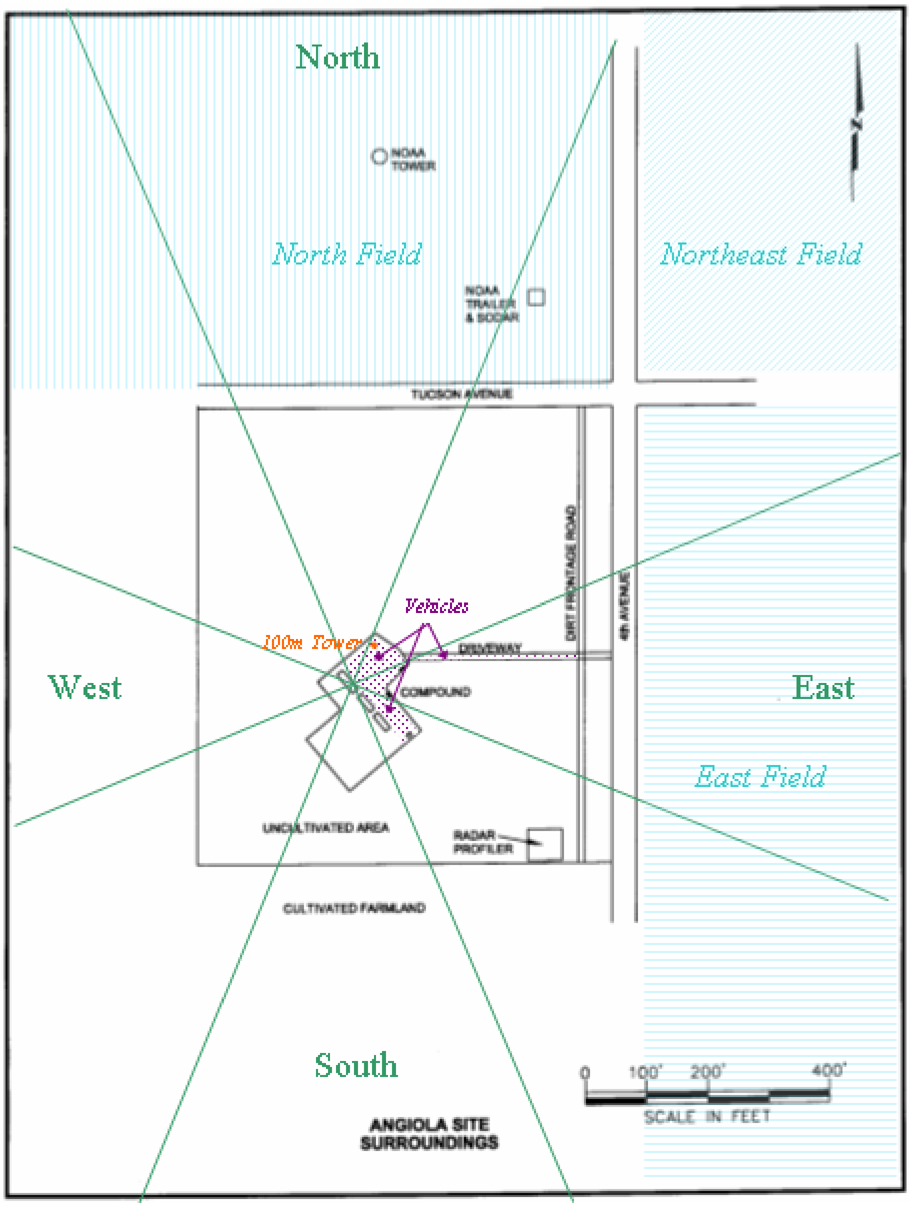


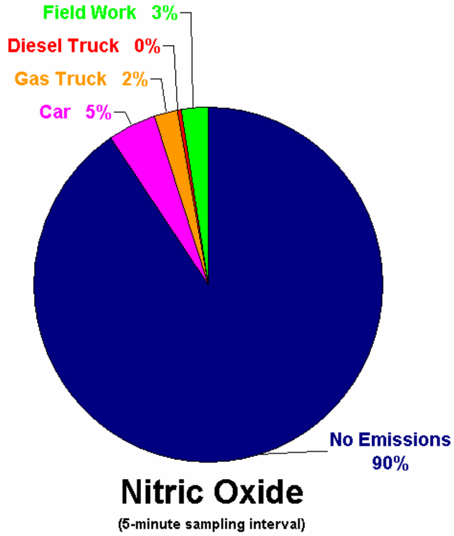
Figure 2-7. Diagram used to determine source locations relative to the measurement sites.

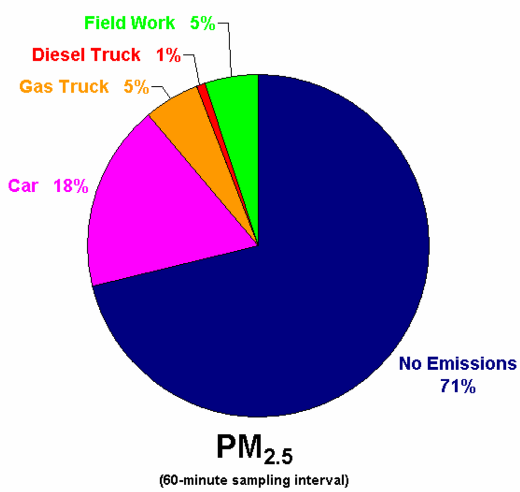
Meteorological data measured on location at five-minute intervals consisted of scalar wind speed, wind direction, and wind direction variability (sigma wind direction). The image data were cross-referenced with the wind direction data to determine which time periods had observable local emissions sources upwind of the air quality monitors.

Data for nitric oxide (NO) and particulate matter ($PM_{2.5}$, and PM_{10}) were obtained for the Angiola site. These species were chosen because of their relationship to the types of emissions sources thought to be present in the vicinity of Angiola. NO measurements were taken at five-minute intervals and PM measurements were taken hourly. The air quality data were cross-referenced with the upwind emissions event data and classified by source type.

3. RESULTS AND DISCUSSION

For most of the samples taken, local emissions sources were not observed upwind of the NO and PM monitors. Relative percentages of samples taken during time periods with and without observed influences are shown in **Figure 3-1**.





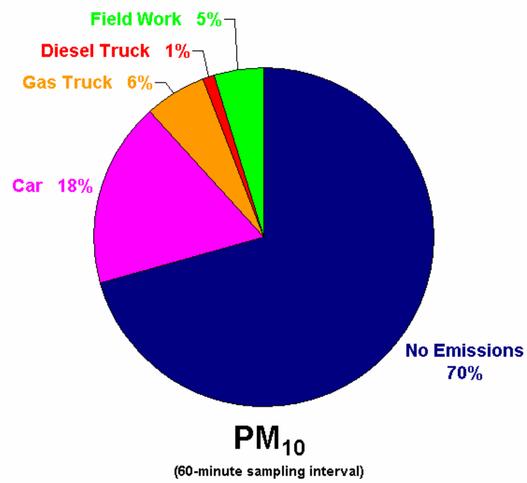


Figure 3-1. Percent of measurements influenced by emissions at least once per sampling interval vs. percent of measurements not influenced by emissions during any part of interval.

For the nitric oxide samples, 90% were taken when no emissions sources were observed. Five percent were taken when car activity was observed, two percent during gas truck activity, and three percent when there was field work activity. For the PM samples, 70% were taken when no emissions were observed, 18% when cars were observed, 5-6% when gasoline-powered trucks were observed, and 5% during field activity.

Statistical analyses of observations compared to measurements were not possible because insufficient numbers of the measurements were taken when local emissions sources were observed. Therefore, comparisons were limited to time-series analyses. Time-series plots of NO, $PM_{2.5}$, and PM_{10} concentrations were created, and data points were color-coded according to local emissions source types. The plots were then examined for evidence of temporal correlation between species concentration variations and observed local emissions events. For nitric oxide, plots were created for each full month (October, November, December, and January). For $PM_{2.5}$ and PM_{10} data, one plot each was produced for the entire time series (October-January). These six plots can be found in Appendix A. Three detail plots (**Figures 3-2 through 3-4**) were also produced of the December nitric oxide measurements and are labeled Detail A, B, and C. These three detail plots provide examples of the basic findings of this study for both the NO and PM data.

Generally, the variations in NO concentrations were found to be more likely due to regional rather than local activity, as shown by the time series detail plots below. On December 6th (Detail A), the midday samples of NO show steadily decreasing concentrations despite a long period of continuous gasoline truck activity upwind of the monitors. The range of NO concentrations during periods of upwind activity is significantly smaller than the range of NO during the entire four-day period. The December 12-15 time-series plot (Detail B) shows similar results for local upwind field work and car activity.

For a few events during this study, emissions from local activities might correlate with NO concentration variability at Angiola, but the number of such potential events is far too small to establish a statistical relationship. On December 19th, for example, there was an extended period of continuous field work upwind of the monitors. Nitric oxide concentrations (in Detail C) steadily rose soon after the onset of the work, and then fell back to their previous levels after the activity ceased. This type of correlation, however, was not at all typical of the data sets. The previous time series shown in Detail A and B were much more representative of the entire data sets.

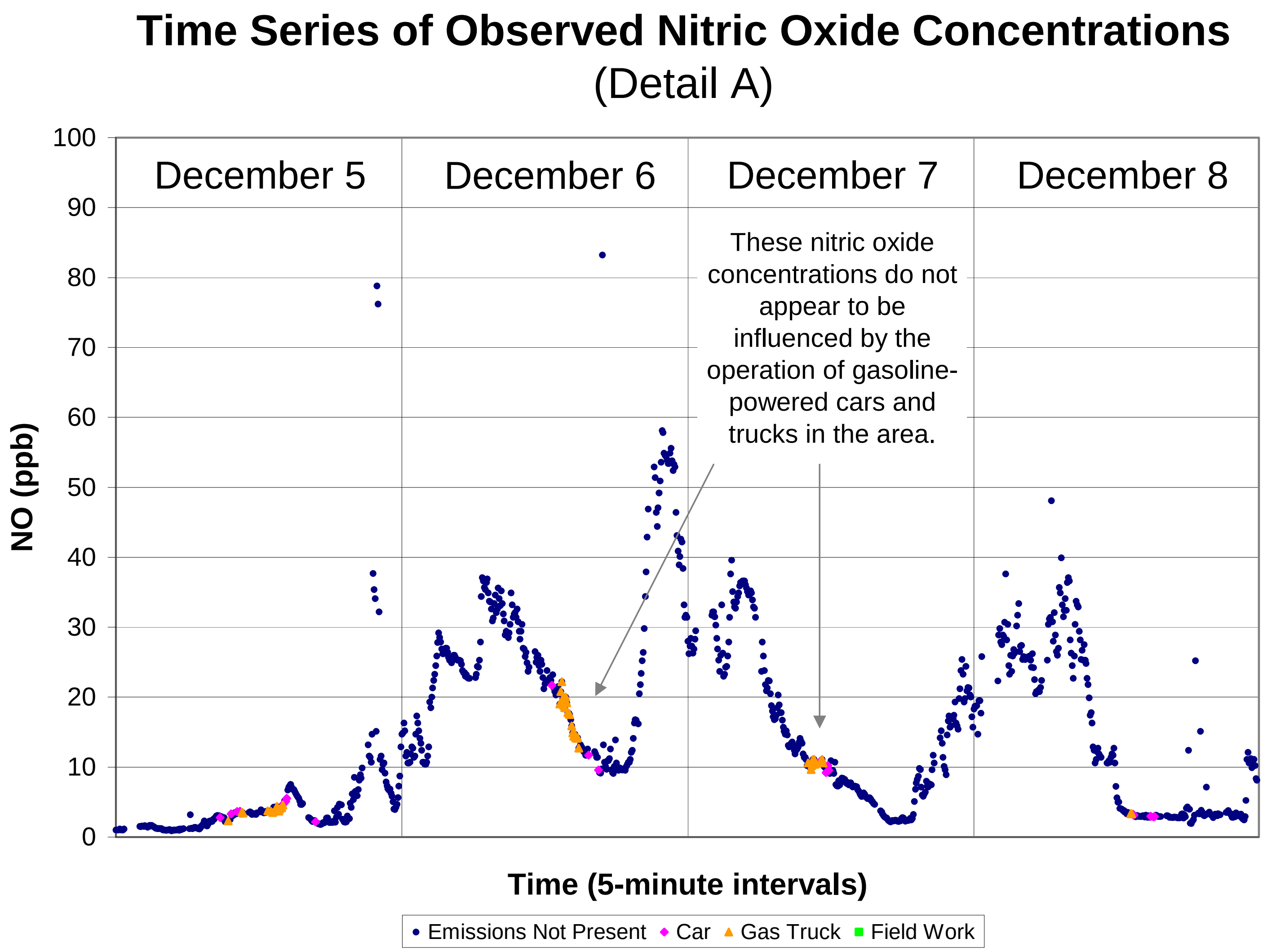


Figure 3-2. Time series of observed nitric oxide concentrations – December 5-8, 2000 (Detail A).

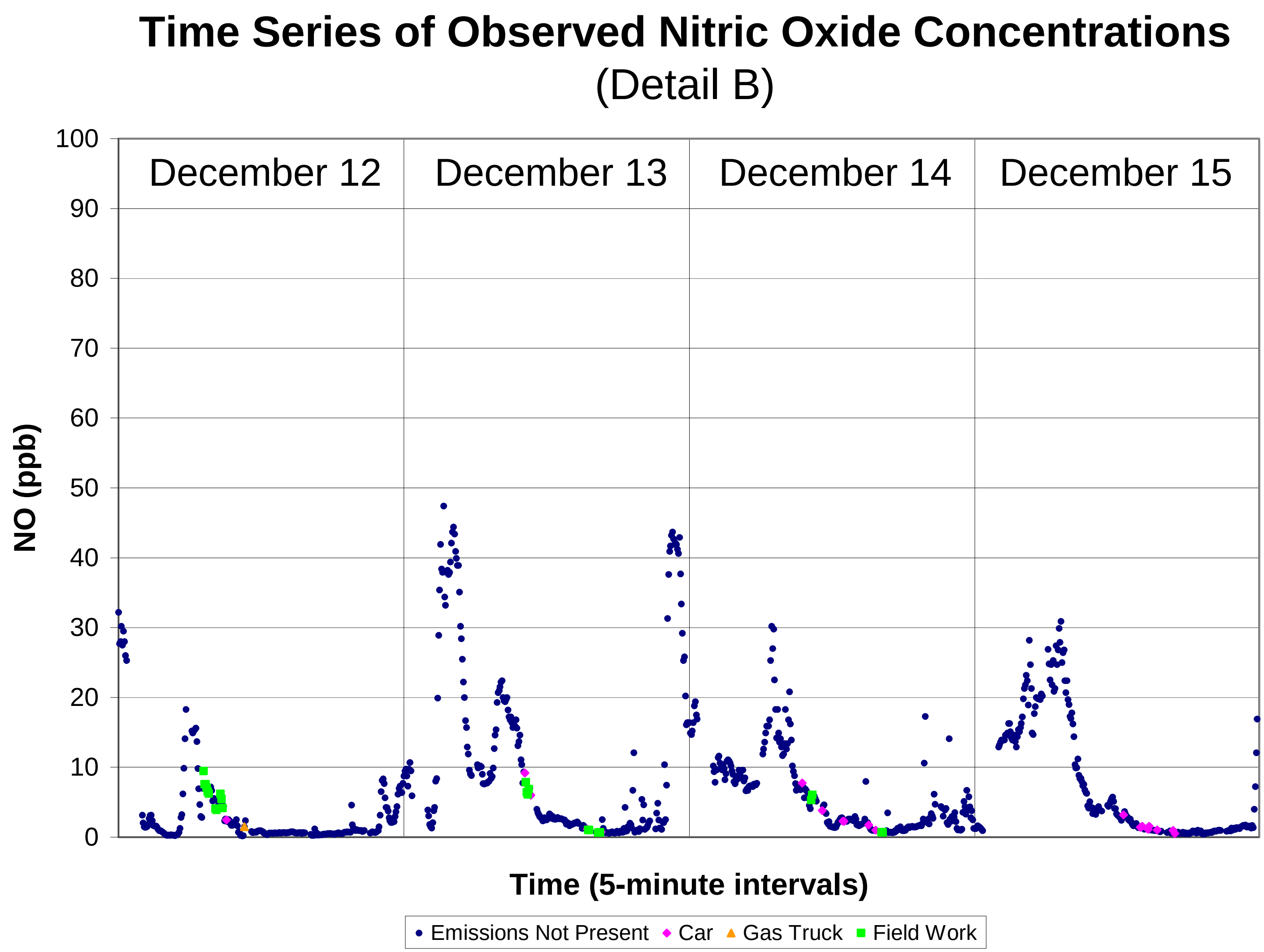


Figure 3-3. Time series of observed nitric oxide concentrations – December 12-15, 2000 (Detail B).

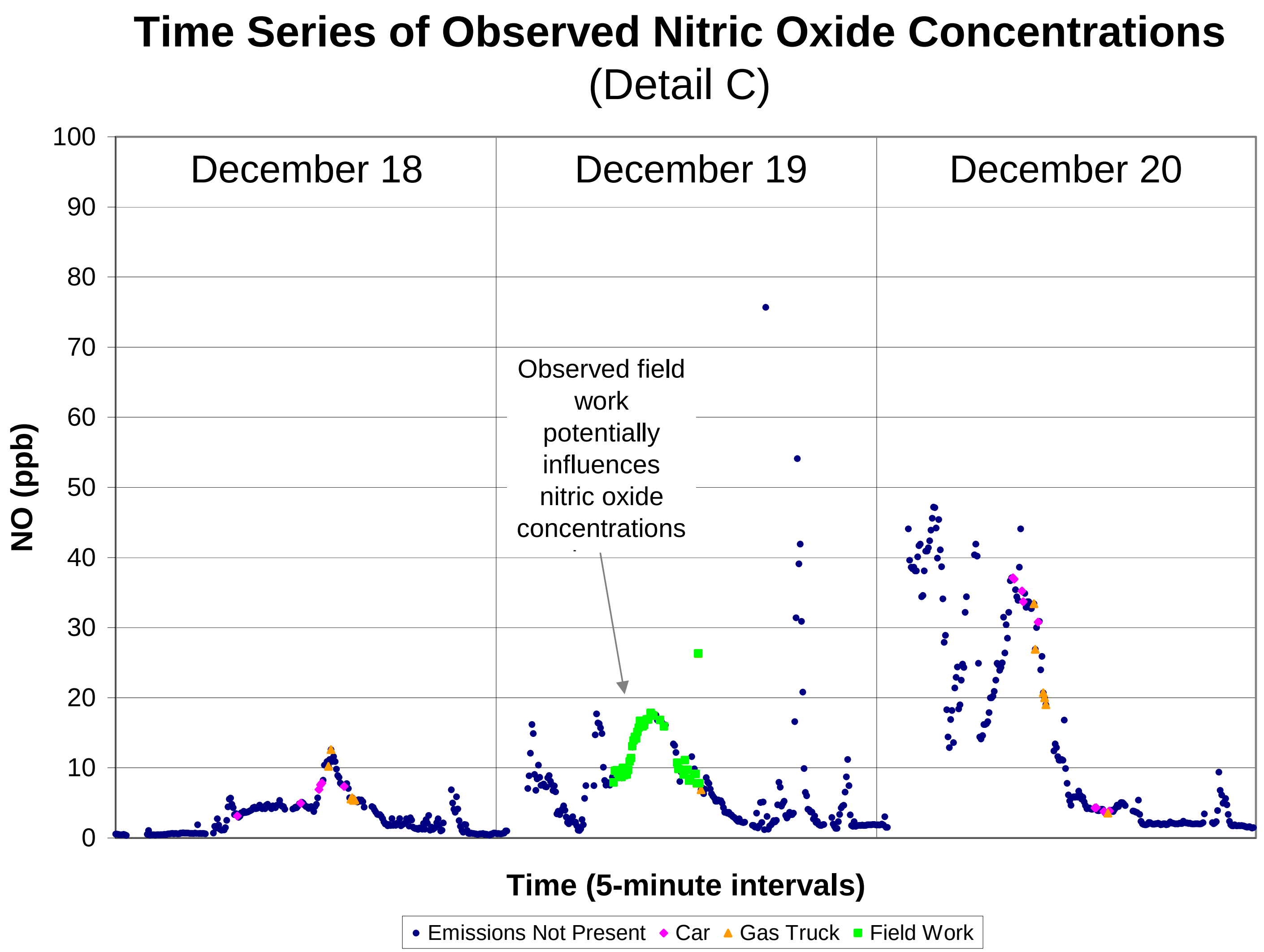


Figure 3-4. Time series of observed nitric oxide concentrations – December 18-20, 2000 (Detail C).

4. CONCLUSIONS

This study has determined that the NO, $PM_{2.5}$, and PM_{10} concentrations measured at the Angiola monitoring site are not significantly affected by local emissions events. The concentration variability of these species during local upwind emissions events is typically much smaller than the variability evidenced in the entire dataset for each species. This study concludes that samples taken at the Angiola site are representative of regional background concentrations of NO and PM, as was intended. A database of observations and samples was compiled in Microsoft Access and provided to the California Air Resources Board. See Appendix C for documentation.

APPENDIX A

TIMES SERIES OF OBSERVED NITRIC OXIDE CONCENTRATIONS

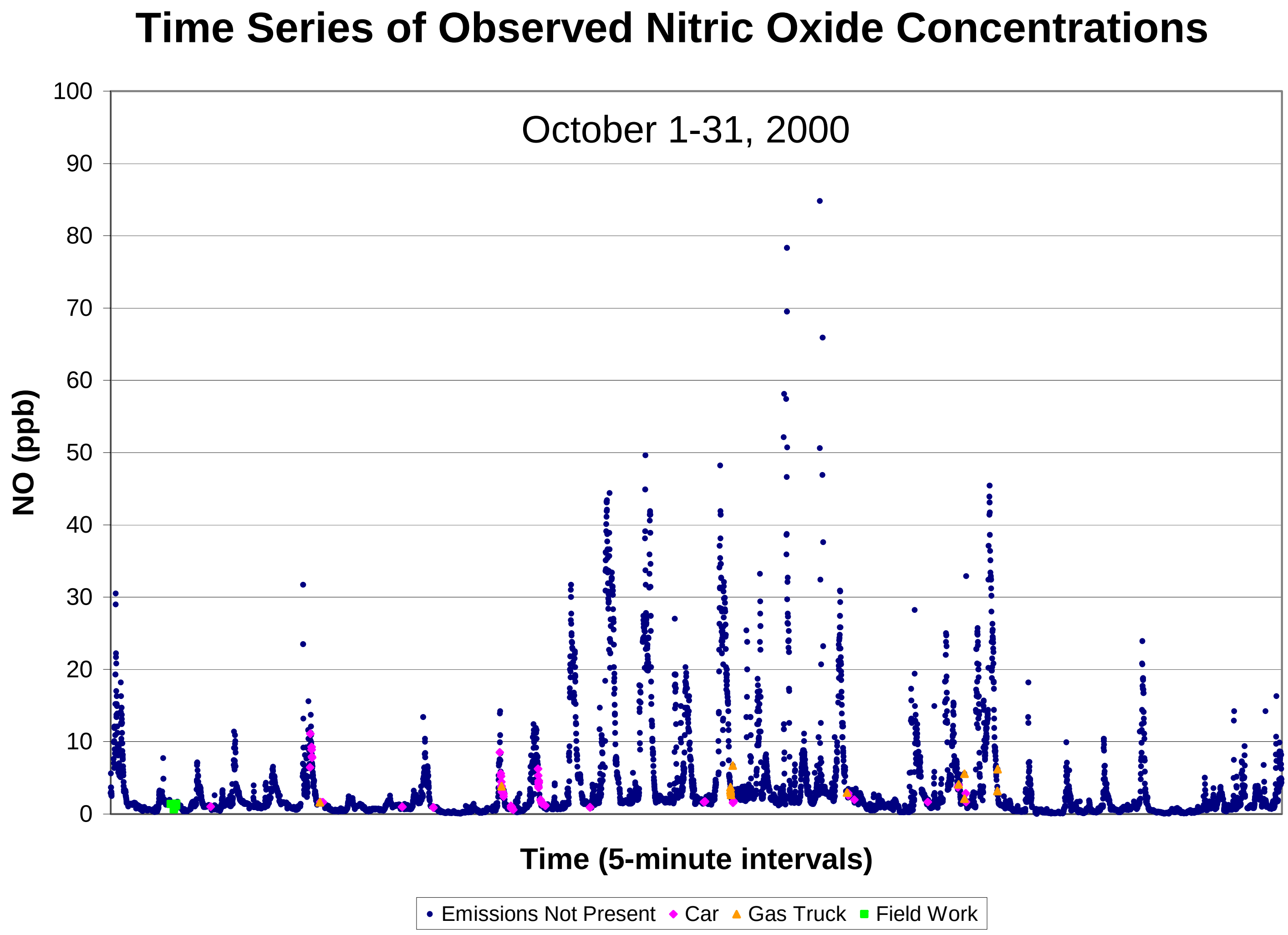


Figure A-1. Time series of observed nitric oxide concentrations – October 2000.

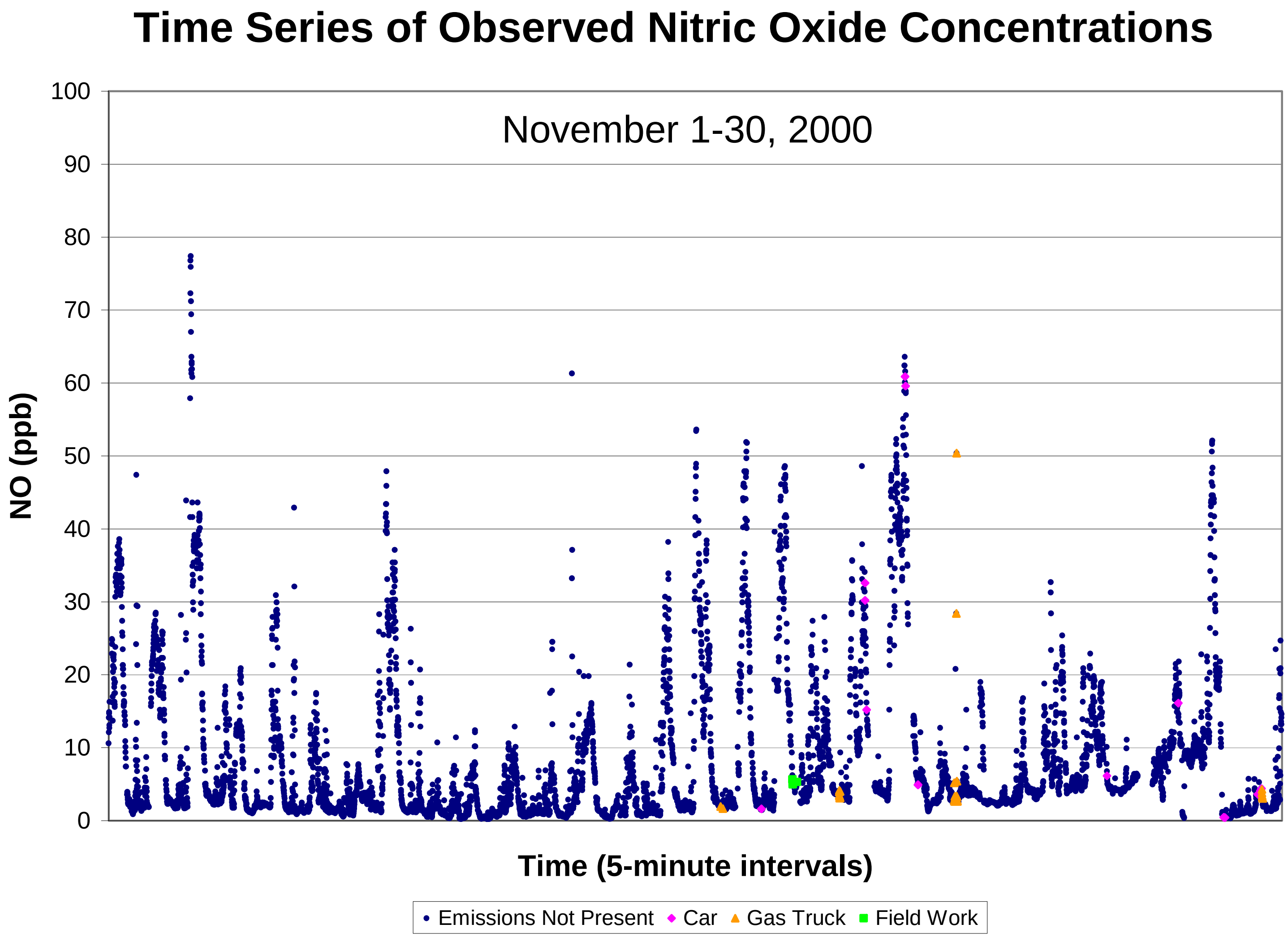


Figure A-2. Time series of observed nitric oxide concentrations – November 2000.

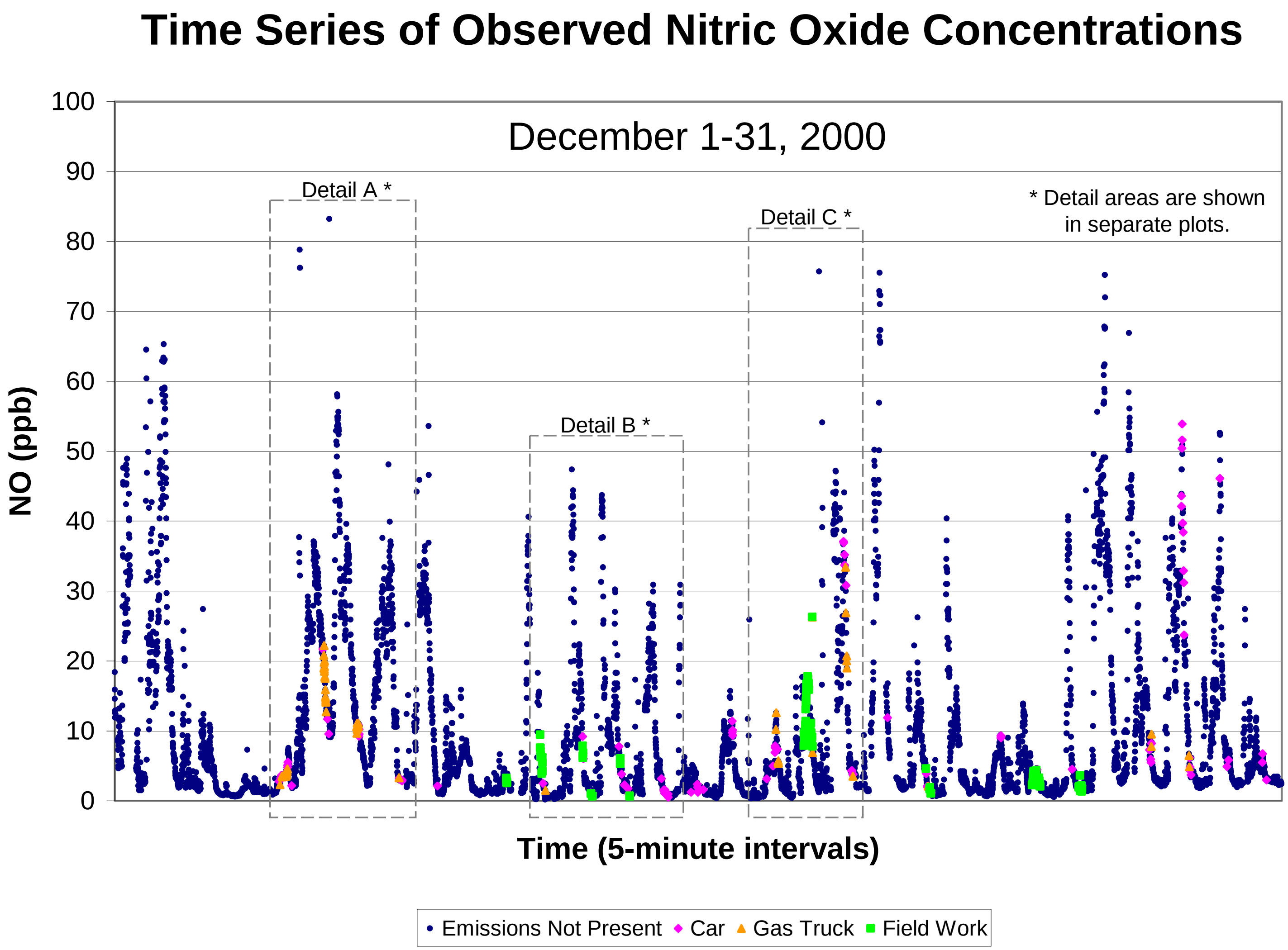


Figure A-3. Time series of observed nitric oxide concentrations – December 2000.

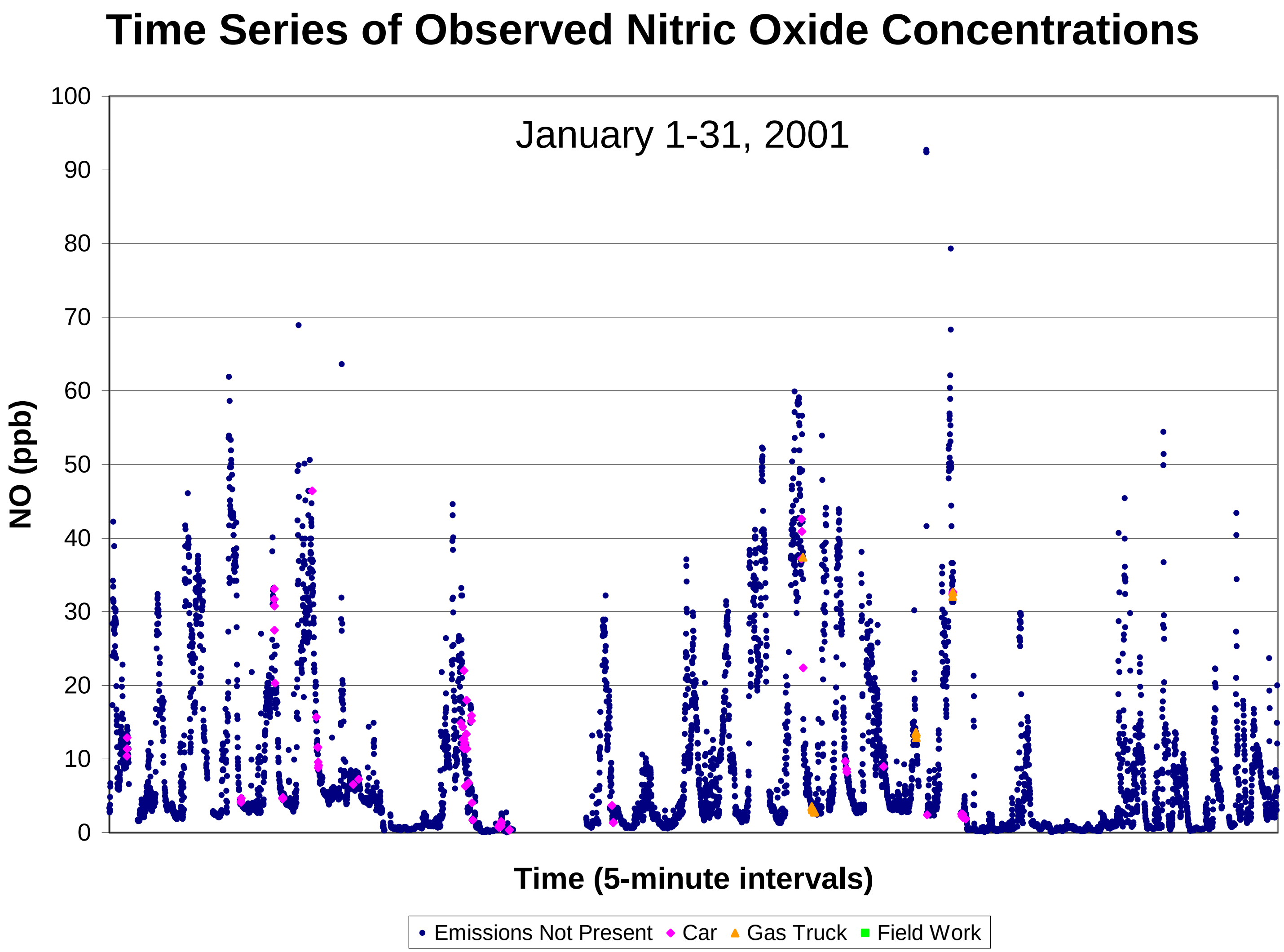


Figure A-4. Time series of observed nitric oxide concentrations – January 2001.

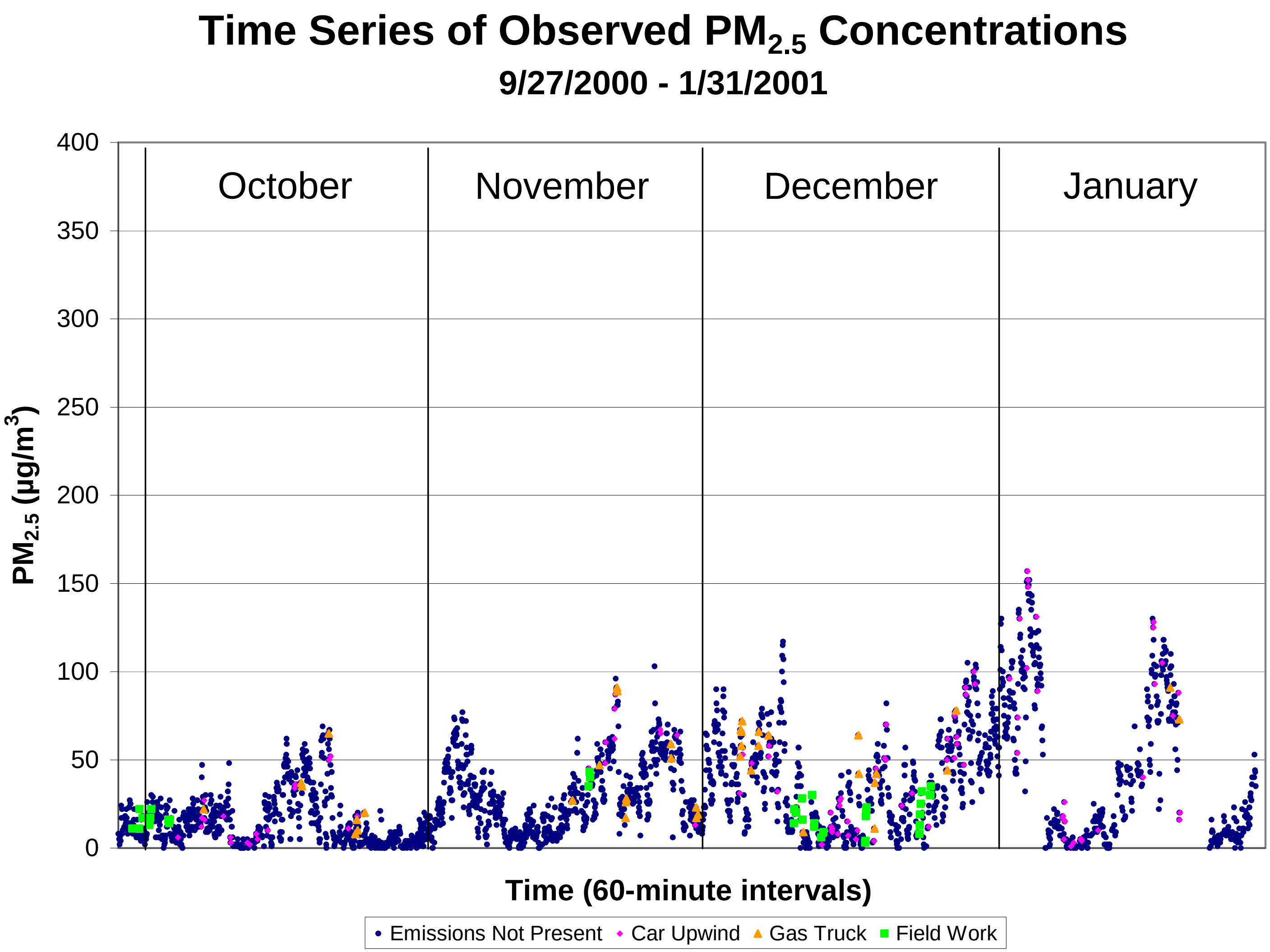


Figure A-5. Time series of observed $PM_{2.5}$ concentrations – September 2000 to January 2001.

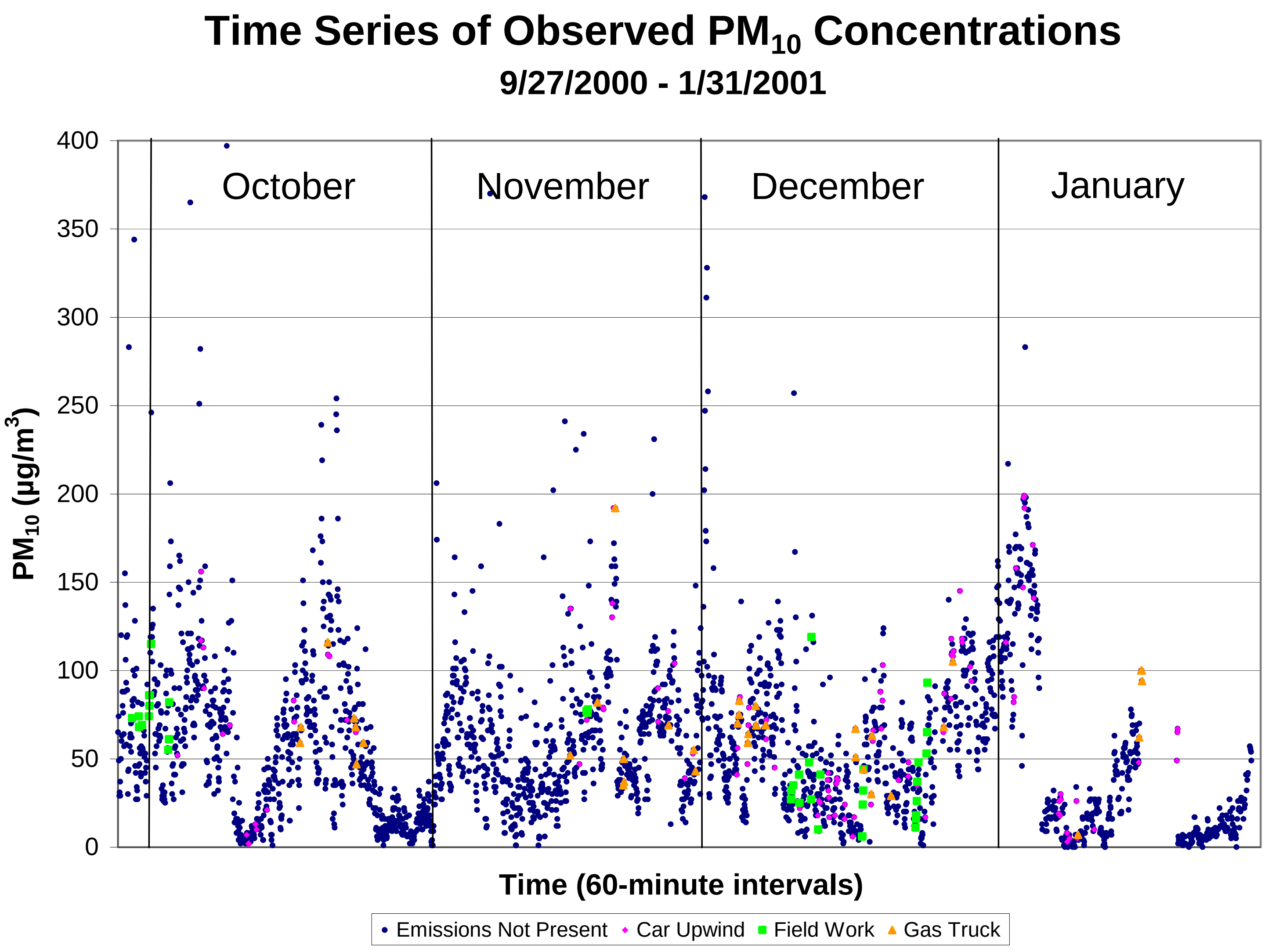


Figure A-6. Time series of observed PM_{10} concentrations – September 2000 to January 2001.

APPENDIX B

ABSTRACT FOR PRESENTATION TO AMERICAN ASSOCIATION FOR AEROSOL RESEARCH (AAAR) CONFERENCE JULY 2003

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ABSTRACT

It is often difficult to quantify the effects of local emissions sources on ambient air quality measurements. In an effort to determine the potential effect of local short-term emissions-related events, we have constructed a continuous, 4-month photographic record of the immediate area surrounding the Angiola air quality monitoring site. This site is one of the most essential monitoring sites of the California Regional PM_{10}/$PM_{2.5}$ Air Quality Study (CRPAQS) of California's San Joaquin Valley. Our analyses of this observational record and the ambient data will reveal the relationship, if any, of ambient air quality measurements with local or short-term emissions sources. With our findings, we hope to validate the fitness of the Angiola monitoring site to represent regional conditions, rather than local influences.

Digital camera images of the entire area surrounding the Angiola site were captured during daylight hours at two- to three-minute intervals, from September 2000 through January 2001. This record of photographic images will be examined and specific time periods logged according to whether local emission sources were observably present or not, the type of source, and its location. These data will be cross-referenced with measurements of wind direction, speed, and variability at each time. We will use the cross-reference to classify each air quality datum as to whether or not it could have been influenced by local activities upwind of the monitors. We will then group the air quality data according to their influencing source types for statistical analyses and intercomparisons. Our initial analyses will cover datasets for NO, $PM_{2.5}$, and PM_{10}. We will determine the extent to which specific activities from the observational record correlate with ambient air quality patterns, which may include spatial patterns, temporal patterns, variations in particle size distributions, and variations in chemical speciations. If no significant differences are found, we will interpret the findings as supporting evidence that the Angiola site is influenced almost exclusively by regional-scale emissions—as it was intended. If evidence of correlations exists, this study may provide corroboration of measurement data and/or other data analyses (such as chemical mass balance modeling). These analyses may also help to explain discrepancies between expected ambient conditions (which are modeled from emission inventories) and real-world ambient measurements or estimated source contributions. Finally, these analyses may demonstrate the local-versus-regional nature of any observed exceedances of air quality standards.

APPENDIX C

DATABASE DOCUMENTATION

DATABASE DOCUMENTATION

This section is intended as a reference for those interested in specific information about the Microsoft Access database '`CRPAQS_T43_AngiolaLocalEvents.mdb`' and how the data analysis was implemented in this study. It also gives details on quality assurance procedures, assumptions, methods of categorization, and data sources. The database has three types of objects: Tables, Queries, and Forms. These will be referred to below using capitalized titles. Object titles will be in Courier font.

All images analyzed were referenced by filename in the `Camera-Activity_Data` Table and viewed through the `Data_Entry_Form`, which was used to input the categorization data. The categorizations were stored in the same Table. The raw meteorology and PM data was stored in Tables with the suffix `_SUBSET`. The remaining Tables were used for the data as it was averaged hourly, grouped by day of week, and grouped by wind direction.

The Queries in the database were named sequentially (Q1, Q2, Q3, ...) as to the order in the data processing that they were used. They begin with Queries that group the camera images into 5 minute time bins (Q1) and then assign the wind direction to each of these time bins (Q2). Next, Q3 is used to determine which categorized sources were upwind of the monitors and create a new table with this information. Queries 4 through 6 are used to extract the specific 5-minute and 60-minute time bins where each type of source was upwind of the monitors in 10% to 100% of the images taken within that interval. Query 7 then extracts the air quality data that was measured in these times where upwind sources of each type were present.

During the data categorization and analysis process, several observations and assumptions were made. Cars and non-diesel trucks were observed to be operated only for short times (on the order of seconds to a couple of minutes), with the exception of the scissor lift. Diesel trucks were assumed to be running during the entire time they were present, and therefore wound up classified as usually operating on the order of one to twenty minutes. Field work, when observed, often lasted for significant portions of the day, on the order of a few hours up to twelve hours. Below are some assumptions made.

- Any automobiles that were not moving were not emitting anything.
- Any personal use automobiles (cars or trucks) were categorized as 'cars' in the database.
- People on site did not affect emissions (driving cars and scissor lift did, though).
- When diesel trucks are present they are probably left running.
- When the scissor lift is being used it is 'on' all the time, including when it is near the tower.
- The scissor lift is gasoline-powered.
- Unknown trucks were gasoline-powered.
- The tower lift itself did not produce emissions.
- Most road traffic was ignored – it was assumed that most of the passing road traffic was 'background' and wasn't caught on video.

- For intervals with incomplete data, the data collected are representative of the entire interval.
- Wind direction at a specific (measured) time was assumed to represent the wind direction for several minutes before it – long enough for the source to arrive at the monitor.

The following describes details about the raw data used.

<u>Nitric Oxide Data</u>
Criteria for dataset selection:
Observation value had to be greater than zero. (This is also Primary_flag=V0, QC_status=1, and Obs_Type_code=1B).
Units: ppb

<u>Meteorology Data</u>
Data were from Angiola 100m tower.

Wind speed and direction data are from the 23m sensor for 9/27/00 - 11/14/00 and from the 10m sensor for 11/15/00 - 1/31/01 (complete datasets were not available for either tower height).

Time periods with no data:
(33 days out of 153 = 22%)
10/19/03, 10/25/00 – 11/14/00, 12/3/00, 1/2/03-1/3/03, 1/24/01 – 1/31/01

Data used:
WSS - Scalar_Wind_Speed (m/s)
WD – Wind Direction (degrees)
SIGWD – Sigma Wind Direction (degrees)

Criteria for meteorology dataset selection (QC):
Wind measurements with speeds less than 0.5 m/s and greater than or equal to 5.5 m/s were not used.
Wind measurements with Sigma Wind Directions greater than or equal to 22.5 degrees were not used.

<u>$PM_{2.5}$ and PM_{10} Data</u>
Criteria for data selection:
QC Status of 1B and concentration greater than zero.
Units: ug/m^3 (stdT&P)

<u>Time resolution of data</u>
Image frequency: 2-3 min.
Meteorology (Wind Speed, Wind Direction, Sigma Wind Direction): 5 min.
NO: 5 min.
$PM_{2.5}$: 60 min.
PM_{10}: 60 min